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FACULTY OF COMPUTER SCIENCE AND AUTOMATION

COMPUTER SCIENCE MEETS AUTOMATION

VOLUME I

Session 1 - Systems Engineering and Intelligent Systems

Session 2 - Advances in Control Theory and Control Engineering

Session 3 - Optimisation and Management of Complex Systems and Networked Systems

Session 4 - Intelligent Vehicles and Mobile Systems

Session 5 - Robotics and Motion Systems

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

Table of Contents

C O N T E N T S

2 Advances in Control Theory and Control Engineering

Paper submitted after copy deadline

2 Advances in Control Theory and Control Engineering

52nd Internationales Wissenschaftliches Kolloquium
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K. Meissner / H. Hensel

A 3D process information display to visualize complex process conditions in the process industry

Human-machine Interface

1. Introduction

In the last few years, a clear increase in system complexity of production sites as a result of the technical developments in the process industry, and thus a not insignificant increase in the requirements of the operators of such systems, has been recorded. On the one hand, for cost reasons the degree of automation and the productivity of the systems have further increased, and on the other hand the number of system operators per system and shift have continued to be reduced. The information capacity to be supervised by an individual operator has thus been constantly rising [6]. The resulting mental load and the possible overloading of the operator described by Grams [4] result in an increasing error potential in the operator actions, particularly in emergency and stress situations. The solution methods already discussed in the technical literature in order to tackle this problem stretch on the one side from improved visualization, like the mass data display [3] or the 3D-visualization [8], which should unburden the user. On the other side, complex expert systems [1] were developed, which are supposed to actively support the operator during the processing by means of artificial intelligence methods, mathematical prognosis models and stored process knowledge [5].

In this paper, previous attempts at an improvement in visualization, in particular icon-based visualization [2] [7], are taken up and a new procedure with simple 3D icons is described. For this, the realizations of the cognitive science are to be used, in order to consider the abilities and the weaknesses of the human perception. It uses a cognitive scenic approach, which is to facilitate a recognizing and a classifying of critical process conditions or process tendencies of the operator. The second section presents the new icon and the imbedding into the 3D world. Here the cognitive scenic aspect of this visualization method comes into being. The next section describes the process of the user evaluation and the conclusion forms a summary of the results as well as a look at further works.

2. Implementation

Based on the problems described above, a new type of icon based mass data display was developed. It contains a 3D view of several process values as figure 2 shows. Each value is represented by an icon made-up of a cylindrical symbol with an inner area, an outer ring, a trend line, a forecasting pointer and a label as shown in figure 1.

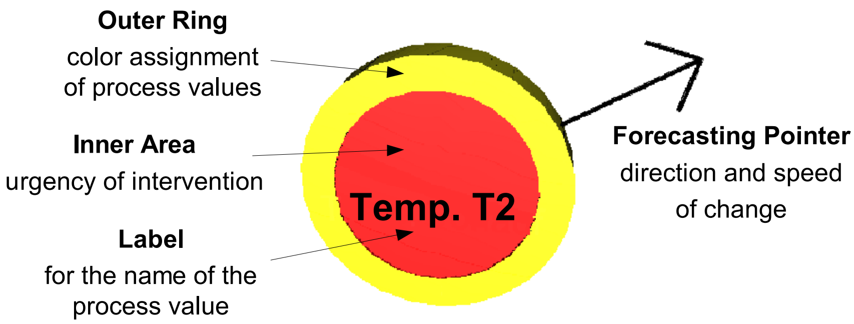
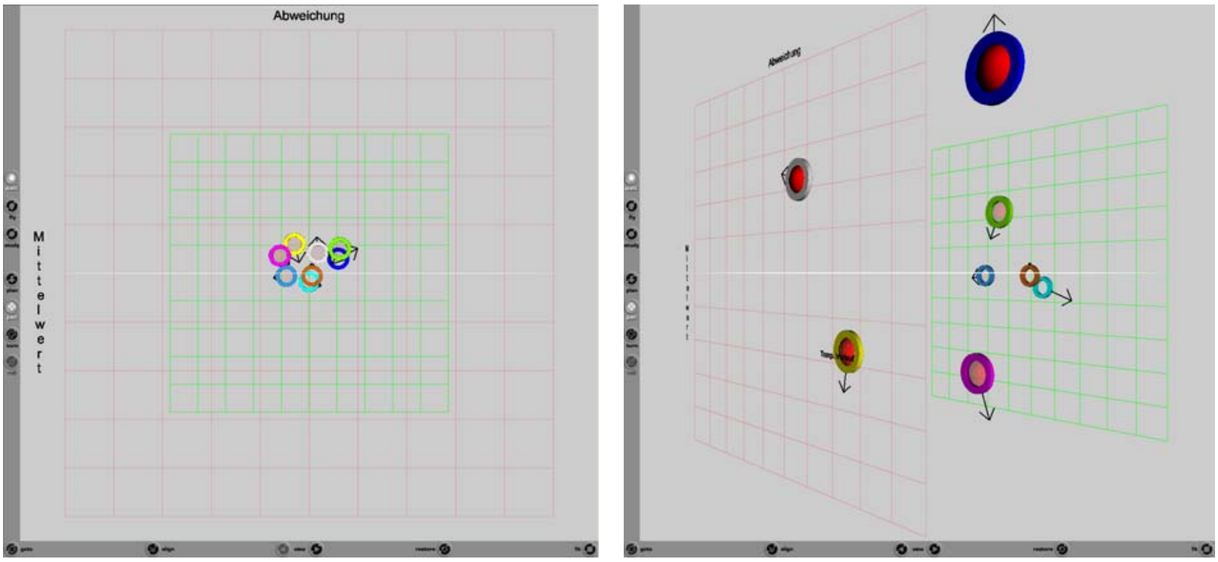


Figure 1: Design of the 3D visualization icon

The inner area shows the urgency of the operator intervention and changes his transparency. A clear area means that no intervention is necessary (figure 2a) and a red area represents a very high need of intervention by the operator (figure 2b). The colored outer ring represents the process value and shows its name in the legend. The forecasting pointer shows the operator the direction the process is running before and after an intervention. The trend line points up the history of the process value and the label will only be shown if the mouse pointer touches an icon. If a process value (e.g. Temp. T2) runs out of the limits, the inner area will change to red and the icon will enlarge by moving to the front. This scenic visualization indicates the importance of attention by the operator. Values close to the setpoint are smaller, with a transparent inner area and they are localized in the middle of the display. Therefore the operator can recognize the system state with one view only. If there are small icons in the middle of the display and outside the inner red area, the process is running within the specification [9].

In the test environment, the visualization is connected to the technical process via OPC. A self developed set of engineering tools gives the engineer the opportunity to generate the code for the visualization icons and to create the connection between the icons and the process values.



a) Good state of the process b) Bad state of the process

Figure 2: Views of the 3D process information display (3D-PID)

3. User Evaluation of the 3D process information display

Due to the range of the investigations and evaluations − altogether 92 questions in ten subject areas − only the most important results can be presented here. The entire results are the subject of a further publication, which will appear in due course. With the accomplished questioning, the possibilities of different representational forms for process data were compared with one another. The newly-developed 3D process information display was contrasted with the traditional representational forms of graphic displays, group pictures and curve representation. In the context of the evaluation, the implementation of the attributes shown in Section 2 and the following questions should be examined:

- How is the usefulness of the characteristics of the icon and the 3D-worlds evaluated?
- Is the navigation in the 3D-world reasonable for the user?

- How obstructive do the errors of the process topology seem?
- How is the overall acceptance of the new visualization system?

Except for the representation of the case history, whose use by the test persons was only partially recognized, all new characteristics of the 3D process information displays were highly evaluated, from positive to above average. This applies in particular to the representation of the urgency display. Navigation in the 3D world was regarded by the testers as unproblematic − this in particular due to the pre-defined observation points. In the view of the test persons, the recognition of abnormalities and the necessity of an intervention was greatly simplified and accelerated through this representation. Due to the connection to traditional process diagrams, the absence of the process topology in the 3D display is not evaluated negatively. The positive evaluation of the questions regarding the acceptance and the general impression of the 3D visualization system rounds off the results of the questioning. The system was consistently rated good to above average in these respects as well.

Parallel to the evaluation of the 3D visualization systems with the help of the questionnaire described above and testing at real systems, the visualization system was presented at various trade fairs, conferences and congresses. In the resulting discussions, in particular the two issues of process topology and coupling with the traditional visualization procedures were discussed. The problem of the strong abstraction of the visualization procedure and the resulting loss of the representation of the process topology was considered to be difficult. The general opinion was however that the gaining of additional information − like the urgency of an intervention, the speed and direction of the deviation and the quick detectability of process conditions − compensates for the loss of the process topology. The increased value of this representation method in contrast to the traditional visualization procedures was confirmed in the talks with experts regarding the function as a summary visualization. Through the coupling integrated in prototypes with the traditional visualization procedures, the requirement for a summary visualization is likewise fulfilled. Only the implementation of the 3D-world through VRML in prototypes was marked as problematic for reasons relating to performance.

4. Application of the 3-D Process Information Display

Having described the evaluation of the visualization system in the previous section, the process of the lime production, by means of which the 3D process information display was tested in practice, should be briefly considered at this point. The raw material for the production of quicklime is extracted through blasting operations in open-cast mining and transported by heavy-duty lorry or conveyor belt for processing. The lumps of calcium carbonate ($CaCO_3$) limestone are mixed with finer coal and filled into the top of a kiln. This lime-coal mixture slowly slides through the firing zones, individually fuelled by gas, oil or animal fat, in which the limestone is deacidified at a temperature of 1,000 °C to 1,300 °C. The quicklime is removed from the bottom of the kiln and transported to bunkers.

The process of lime production was chosen as many different process variables must be monitored in the kiln in order to ensure the quality of the lime. The process variables display varyingly high time constants, which complicate the monitoring and evaluation of the process state. In addition, the concentration of sensors for the monitoring of the process parameters within the processor is very high. This effect has up to now also been negative for the use of conventional display processes, as the process graphics were very overladen and confusing. For this reason, it was suggested that the 3D process information display was deployed as a layered representation, and thus make the quality-relevant process data and information more quickly and simply available to the operator. Both the downtime of the entire plant as well as the reaction times during disruptions could be reduced through the use of the 3D process information display.

5. Summary and Perspective

Through the investigations described in Section 2 and the procedure presented in Section 3, it could be shown that an icon-based cognitive scenic visualization can provide the user, in a simple manner, with a summary representation of the information required to assess the process state. The evaluation in Section 3 shows a high acceptance of the abilities of the 3D-PID by operators and students. The operator is relieved from the influence of stress, allowing potential sources of errors to be minimized. Cognitive scenic visualization should not replace existing visualization forms but rather supplement them, and be understood as abstract and superior visualization components. The number of markers recognizable by the operator as problem-free, the influence of three-dimensional visualization on the mental load of the operator and the possibilities of navigation in the three-dimensional information area are the subject of further investigations.

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